A Study on the Group Sequencing Method in Regards with Transportation in an Industrial FMS

Guillaume Pinot Olivier Cardin Nasser Mebarki

IRCCyN — UMR CNRS 6597
Nantes, France
firstname.lastname@irccyn.ec-nantes.fr

IEEE SMC 2007

Table of Contents

Table of Contents

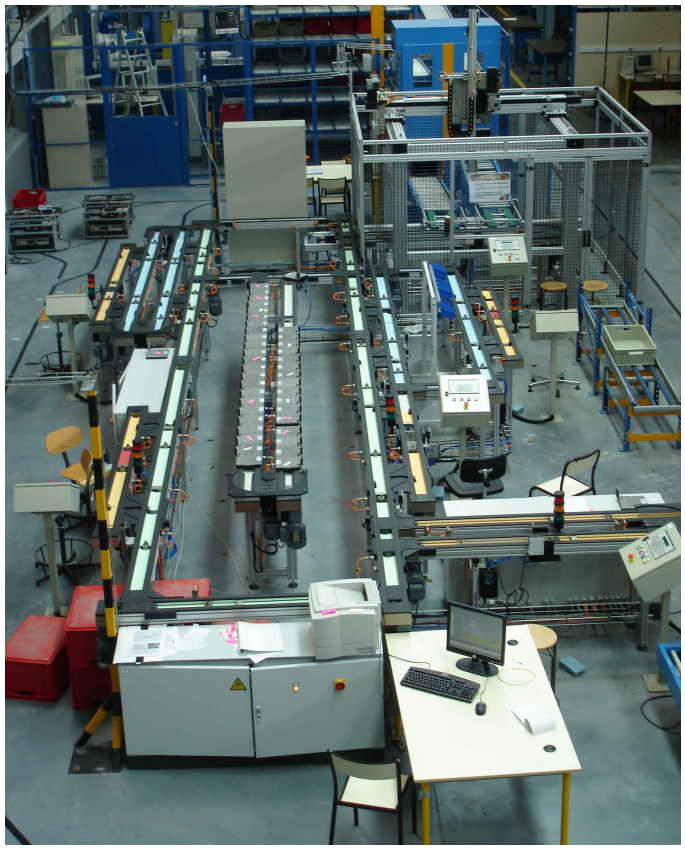
Introduction

Flexible Manufacturing System:
designed to combine high productivity and production flexibility.

Job shop problem: a model used to optimize the performance of FMS.

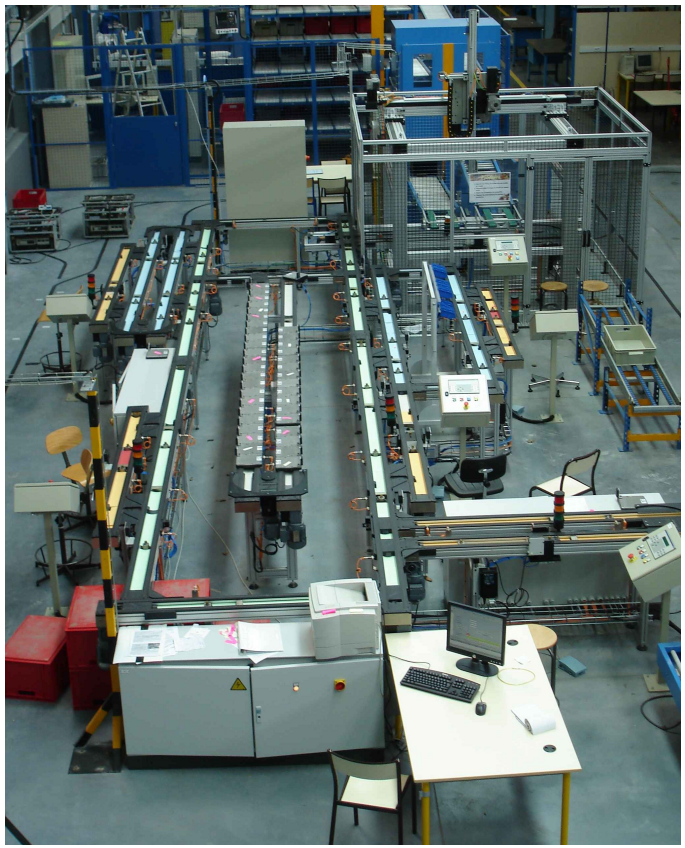
The job shop model is a simplified model of FMS: differences exist between model and reality, the uncertainties (transportation, processing times that may be variable, *etc.*).

Group Sequencing can be a solution to this drawback: it gives sequential flexibility to the job shop solution that allows to absorb some of the uncertainties.



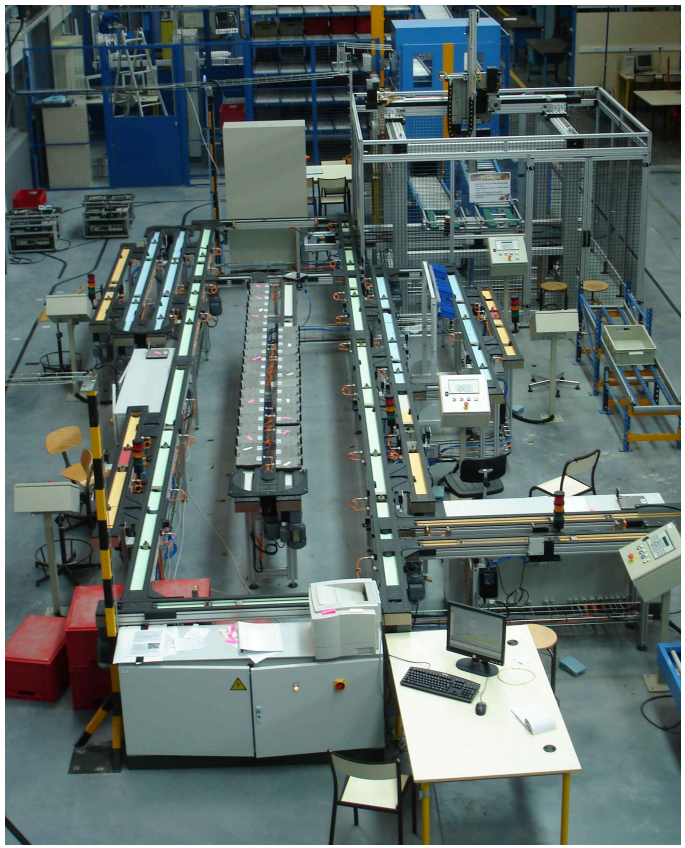
Introduction

Flexible Manufacturing System:
designed to combine high productivity and production flexibility.
Job shop problem: a model used to optimize the performance of FMS.
The job shop model is a simplified model of FMS: differences exist between model and reality, the uncertainties (transportation, processing times that may be variable, *etc.*).
Group Sequencing can be a solution to this drawback: it gives sequential flexibility to the job shop solution that allows to absorb some of the uncertainties.



Introduction

Flexible Manufacturing System: designed to combine high productivity and production flexibility.
Job shop problem: a model used to optimize the performance of FMS.
The job shop model is a simplified model of FMS: differences exist between model and reality, the uncertainties (transportation, processing times that may be variable, *etc.*).
Group Sequencing can be a solution to this drawback: it gives sequential flexibility to the job shop solution that allows to absorb some of the uncertainties.



Introduction

Flexible Manufacturing System: designed to combine high productivity and production flexibility.
Job shop problem: a model used to optimize the performance of FMS.
The job shop model is a simplified model of FMS: differences exist between model and reality, the uncertainties (transportation, processing times that may be variable, *etc.*).
Group Sequencing can be a solution to this drawback: it gives sequential flexibility to the job shop solution that allows to absorb some of the uncertainties.

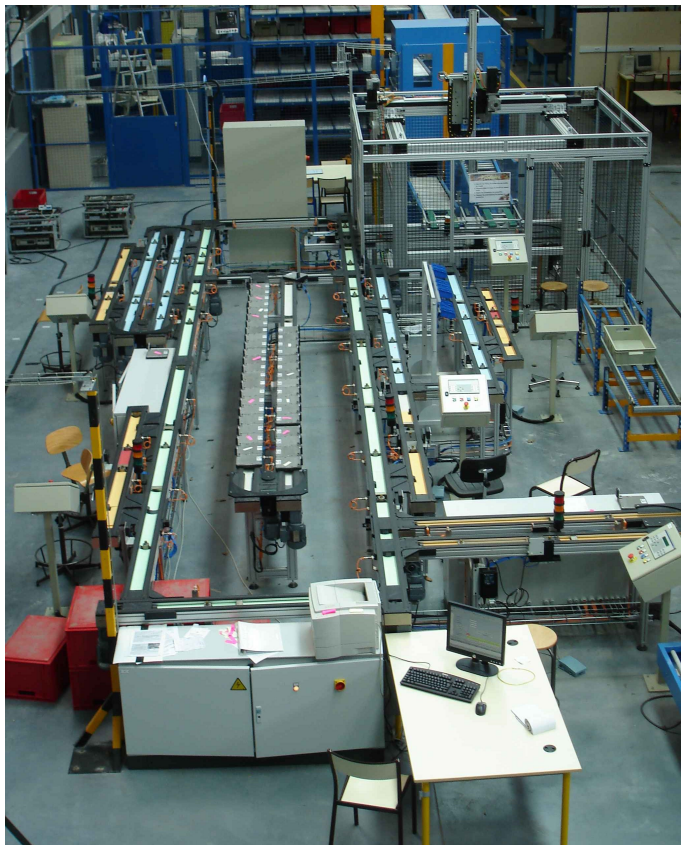


Table of Contents

Group Sequencing

Groups of permutable operations were first introduced in [Erschler and Roubellat, 1989]. The goal of this method is to have a sequential flexibility during the execution of the schedule and to guarantee a minimal quality corresponding to the worst case. For a theoretical description of the method, see [Artigues et al., 2005].

To manage sequential flexibility, this method uses "groups of permutable operations."

Group Sequencing

Groups of permutable operations were first introduced in [Erschler and Roubellat, 1989]. The goal of this method is to have a sequential flexibility during the execution of the schedule and to guarantee a minimal quality corresponding to the worst case. For a theoretical description of the method, see [Artigues et al., 2005]. To manage sequential flexibility, this method uses "groups of permutable operations."

Example: a Job Shop Problem

i represents a job, j an operation, $M_{i,j}$ the resource needed by the operation j from job i, and $p_{i,j}$ the processing time needed by the operation j from job i.

Problem

i	j	$M_{i,j}$	$p_{i,j}$
1	1	1	3
1	2	2	3
1	3	3	3
2	1	2	4
2	2	3	3
2	3	1	1
3	1	3	2
3	2	1	2
3	3	2	2

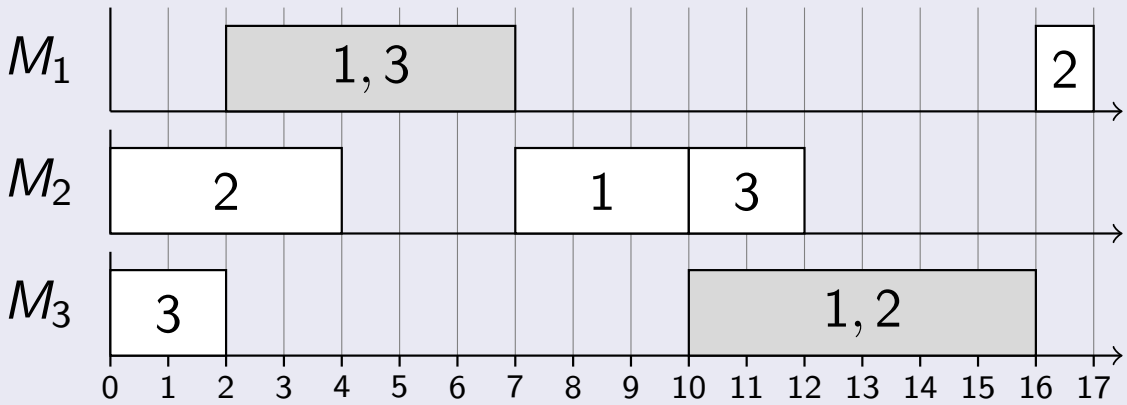
Example: a Job Shop Problem

i represents a job, j an operation, $M_{i,j}$ the resource needed by the operation j from job i, and $p_{i,j}$ the processing time needed by the operation j from job i.

Problem

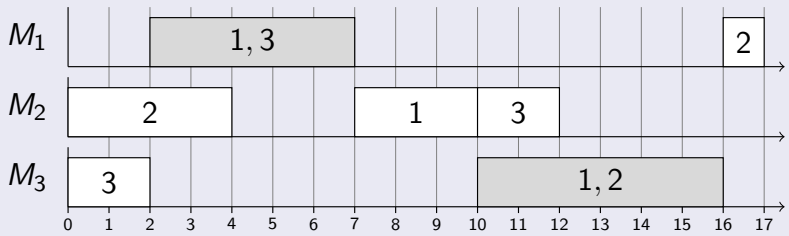
i	j	$M_{i,j}$	$p_{i,j}$
1	1	1	3
1	2	2	3
1	3	3	3
2	1	2	4
2	2	3	3
2	3	1	1
3	1	3	2
3	2	1	2
3	3	2	2

a Solution

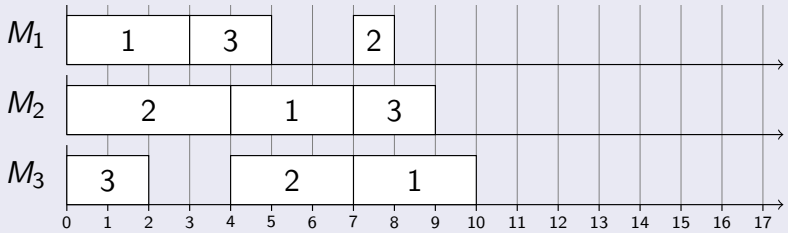


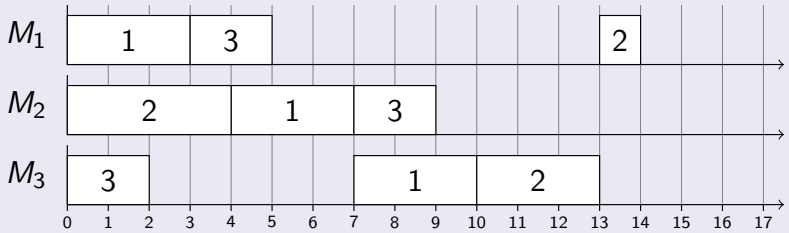
Execution of the Example

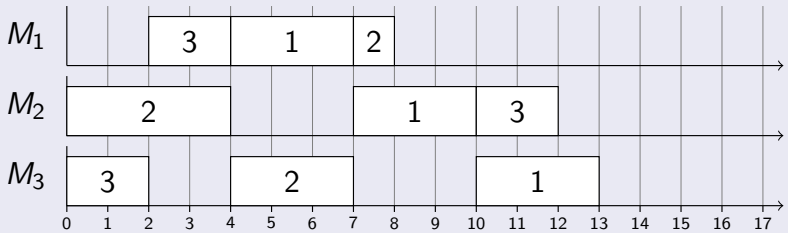
The Group Sequence

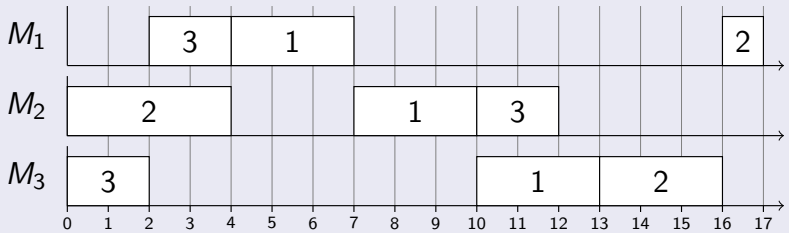


The Corresponding Semi-Active Schedules









Why is Group Sequencing Interesting?

Why is Group Sequencing Interesting?

- predictive reactive method;
- flexibility on sequences;
- evaluation of the group sequence in the worst case in polynomial time for *minmax* regular objectives as C_{max} and L_{max};
- widely studied in the last twenty years: [Erschler and Roubellat, 1989, Billaut and Roubellat, 1996, Wu et al., 1999, Artigues et al., 2005]
- no need to model the uncertainties;
- the method is able to absorb some uncertainties: [Wu et al., 1999, Esswein, 2003] and this presentation.

Why is Group Sequencing Interesting?

Why is Group Sequencing Interesting?

- predictive reactive method;
- flexibility on sequences;
- evaluation of the group sequence in the worst case in polynomial time for *minmax* regular objectives as C_{max} and L_{max};
- widely studied in the last twenty years: [Erschler and Roubellat, 1989, Billaut and Roubellat, 1996, Wu et al., 1999, Artigues et al., 2005]
- no need to model the uncertainties;
- the method is able to absorb some uncertainties: [Wu et al., 1999, Esswein, 2003] and this presentation.

Why is Group Sequencing Interesting?

Why is Group Sequencing Interesting?

- predictive reactive method;
- flexibility on sequences;
- evaluation of the group sequence in the worst case in polynomial time for *minmax* regular objectives as C_{max} and L_{max};
- widely studied in the last twenty years: [Erschler and Roubellat, 1989, Billaut and Roubellat, 1996, Wu et al., 1999, Artigues et al., 2005]
- no need to model the uncertainties;
- the method is able to absorb some uncertainties: [Wu et al., 1999, Esswein, 2003] and this presentation.

Why is Group Sequencing Interesting?

Why is Group Sequencing Interesting?

- predictive reactive method;
- flexibility on sequences;
- evaluation of the group sequence in the worst case in polynomial time for *minmax* regular objectives as C_{max} and L_{max};
- widely studied in the last twenty years: [Erschler and Roubellat, 1989, Billaut and Roubellat, 1996, Wu et al., 1999, Artigues et al., 2005]
- no need to model the uncertainties;
- the method is able to absorb some uncertainties: [Wu et al., 1999, Esswein, 2003] and this presentation.

Why is Group Sequencing Interesting?

Why is Group Sequencing Interesting?

- predictive reactive method;
- flexibility on sequences;
- evaluation of the group sequence in the worst case in polynomial time for *minmax* regular objectives as $C_{\max}$ and $L_{\max}$;
- widely studied in the last twenty years:
  [Erschler and Roubellat, 1989, Billaut and Roubellat, 1996, Wu et al., 1999, Artigues et al., 2005]
- no need to model the uncertainties;
- the method is able to absorb some uncertainties:
  [Wu et al., 1999, Esswein, 2003] and this presentation.

Why is Group Sequencing Interesting?

Why is Group Sequencing Interesting?

- predictive reactive method;
- flexibility on sequences;
- evaluation of the group sequence in the worst case in polynomial time for *minmax* regular objectives as $C_{\max}$ and $L_{\max}$;
- widely studied in the last twenty years:
  [Erschler and Roubellat, 1989, Billaut and Roubellat, 1996, Wu et al., 1999, Artigues et al., 2005]
- no need to model the uncertainties;
- the method is able to absorb some uncertainties:
  [Wu et al., 1999, Esswein, 2003] and this presentation.

Why is Group Sequencing Interesting?

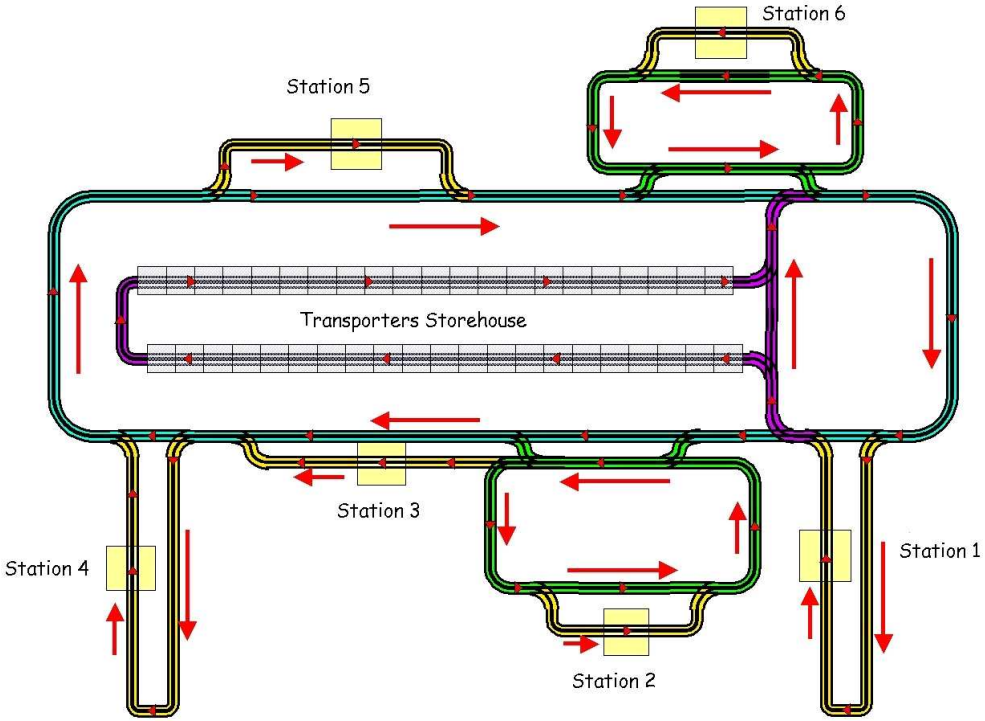
Why is Group Sequencing Interesting?

- predictive reactive method;
- flexibility on sequences;
- evaluation of the group sequence in the worst case in polynomial time for *minmax* regular objectives as $C_{\max}$ and $L_{\max}$;
- widely studied in the last twenty years:
  [Erschler and Roubellat, 1989, Billaut and Roubellat, 1996, Wu et al., 1999, Artigues et al., 2005]
- no need to model the uncertainties;
- the method is able to absorb some uncertainties:
  [Wu et al., 1999, Esswein, 2003] and this presentation.

Table of Contents

The Flexible Manufacturing System under Study

The Flexible Manufacturing System:



A Job shop with transportation.

Group Sequencing:

- Every station keeps up to date a group sequence of operations to execute;
- A station accepts an operation only if it is included into the current group;
- When a group is empty, the station changes to the next group.

Table of Contents

Protocol

We use la14, a job shop problem with no transportation.

Different executions:

- OSS: A predictive schedule that is an optimal solution for the problem without transportation time. The quality is $C_{max} = 1292$. The sequence of operations on each machine are given by the schedule.
- OGSS: A predictive-reactive schedule that is a group sequence where the quality of all semi-active schedules are $C_{max} = 1292$.
- DGSS: A predictive-reactive schedule that is a group sequence where the worst-case quality is $C_{max} = 1382$ and the best-case quality is $C_{max} = 1292$ with more flexibility than OGSS.
- DS: A reactive schedule, using the FIFO rule.

Protocol

We use la14, a job shop problem with no transportation.
Different executions:

- OSS: A predictive schedule that is an optimal solution for the problem without transportation time. The quality is $C_{max} = 1292$. The sequence of operations on each machine are given by the schedule.
- OGSS: A predictive-reactive schedule that is a group sequence where the quality of all semi-active schedules are $C_{max} = 1292$.
- DGSS: A predictive-reactive schedule that is a group sequence where the worst-case quality is $C_{max} = 1382$ and the best-case quality is $C_{max} = 1292$ with more flexibility than OGSS.
- DS: A reactive schedule, using the FIFO rule.

Protocol

We use la14, a job shop problem with no transportation.
Different executions:

- OSS: A predictive schedule that is an optimal solution for the problem without transportation time. The quality is $C_{max} = 1292$. The sequence of operations on each machine are given by the schedule.
- OGSS: A predictive-reactive schedule that is a group sequence where the quality of all semi-active schedules are $C_{max} = 1292$.
- DGSS: A predictive-reactive schedule that is a group sequence where the worst-case quality is $C_{max} = 1382$ and the best-case quality is $C_{max} = 1292$ with more flexibility than OGSS.
- DS: A reactive schedule, using the FIFO rule.

Protocol

We use la14, a job shop problem with no transportation.
Different executions:

- OSS: A predictive schedule that is an optimal solution for the problem without transportation time. The quality is $C_{max} = 1292$. The sequence of operations on each machine are given by the schedule.
- OGSS: A predictive-reactive schedule that is a group sequence where the quality of all semi-active schedules are $C_{max} = 1292$.
- DGSS: A predictive-reactive schedule that is a group sequence where the worst-case quality is $C_{max} = 1382$ and the best-case quality is $C_{max} = 1292$ with more flexibility than OGSS.
- DS: A reactive schedule, using the FIFO rule.

Protocol

We use la14, a job shop problem with no transportation.
Different executions:

- **OSS:** A predictive schedule that is an optimal solution for the problem without transportation time. The quality is $C_{max} = 1292$. The sequence of operations on each machine are given by the schedule.
- **OGSS:** A predictive-reactive schedule that is a group sequence where the quality of all semi-active schedules are $C_{max} = 1292$.
- **DGSS:** A predictive-reactive schedule that is a group sequence where the worst-case quality is $C_{max} = 1382$ and the best-case quality is $C_{max} = 1292$ with more flexibility than OGSS.
- **DS:** A reactive schedule, using the FIFO rule.

Results

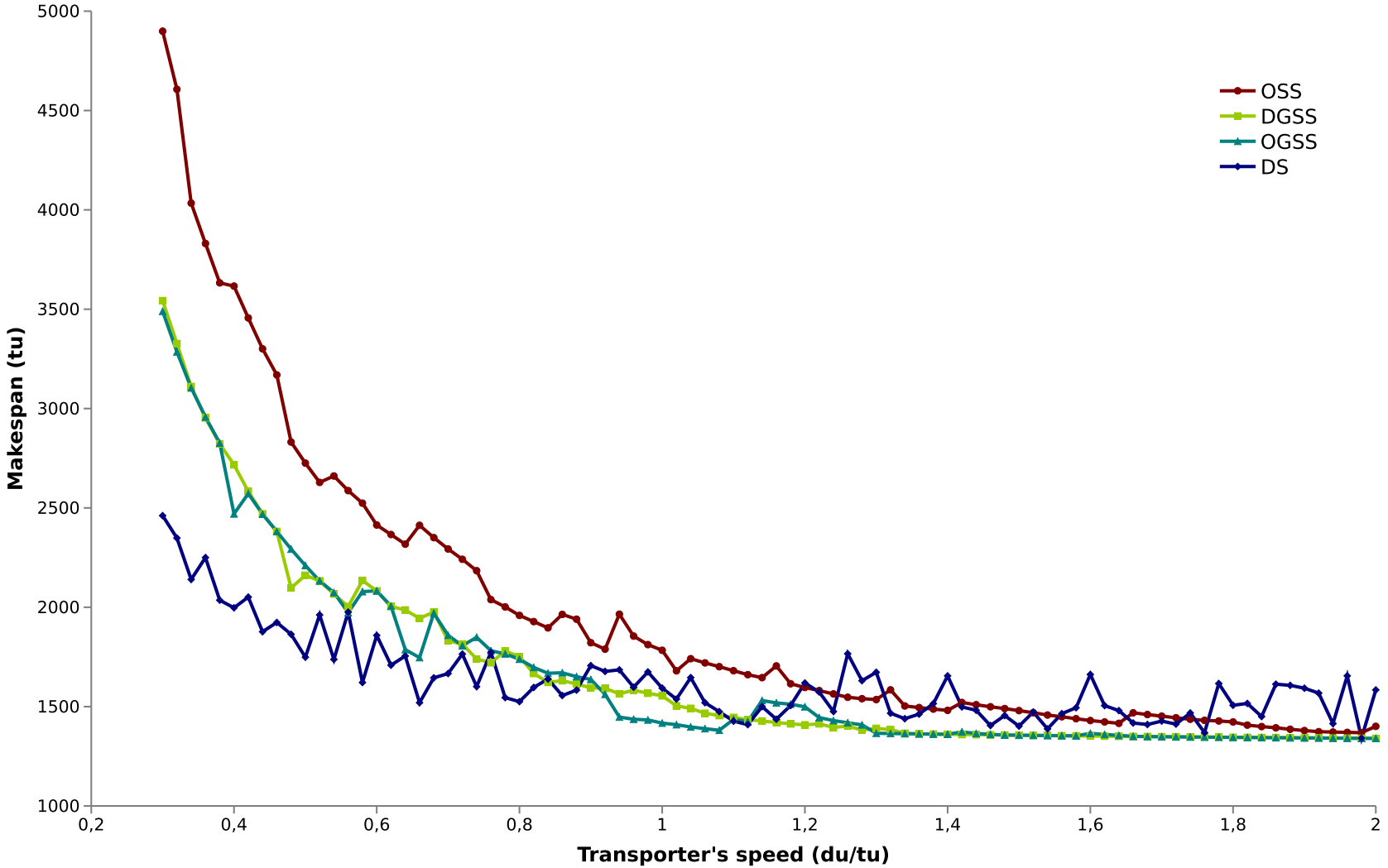

5000
4500
4000
3500
3000
2500
2000
1500
1000
Makespan (tu)
0,2
0,4
0,6
0,8
1
1,2
1,4
1,6
1,8
2
Transporter's speed (du/tu)
OSS
DGSS
OGSS
DS

Table of Contents

Conclusion

We presented:

- the problem of scheduling under uncertainties;
- group sequencing;
- a use of group sequencing on an FMS;
- the effectiveness of group sequencing on an FMS in regards with transportation.

In future works, we will experiment this property on other objectives such as the maximum lateness.

Conclusion

We presented:

- the problem of scheduling under uncertainties;
- group sequencing;
- a use of group sequencing on an FMS;
- the effectiveness of group sequencing on an FMS in regards with transportation.

In future works, we will experiment this property on other objectives such as the maximum lateness.

Conclusion

We presented:

- the problem of scheduling under uncertainties;
- group sequencing;
- a use of group sequencing on an FMS;
- the effectiveness of group sequencing on an FMS in regards with transportation.

In future works, we will experiment this property on other objectives such as the maximum lateness.

Conclusion

We presented:

- the problem of scheduling under uncertainties;
- group sequencing;
- a use of group sequencing on an FMS;
- the effectiveness of group sequencing on an FMS in regards with transportation.

In future works, we will experiment this property on other objectives such as the maximum lateness.

Conclusion

We presented:

- the problem of scheduling under uncertainties;
- group sequencing;
- a use of group sequencing on an FMS;
- the effectiveness of group sequencing on an FMS in regards with transportation.

In future works, we will experiment this property on other objectives such as the maximum lateness.

Bibliography I


Artigues, C., Billaut, J.-C., and Esswein, C. (2005).
Maximization of solution flexibility for robust shop scheduling.
European Journal of Operational Research, 165(2):314–328.


Billaut, J.-C. and Roubellat, F. (1996).
A new method for workshop real-time scheduling.
International Journal of Production Research, 34(6):1555–1579.


Erschler, J. and Roubellat, F. (1989).
An approach for real time scheduling for activities with time and resource constraints.
In Slowinski, R. and Weglarz, J., editors, *Advances in project scheduling*. Elsevier.

Bibliography II


Esswein, C. (2003).
Un apport de flexibilité séquentielle pour l'ordonnancement robuste.
Thèse de doctorat, Université François Rabelais Tours.


Wu, S. D., Byeon, E.-S., and Storer, R. H. (1999).
A graph-theoretic decomposition of the job shop scheduling problem to achieve scheduling robustness.
Operations Research, 47(1):113–124.